Effects of environmental variables on abundance and phenology of immature *Ixodes scapularis* (Acari: Ixodidae)

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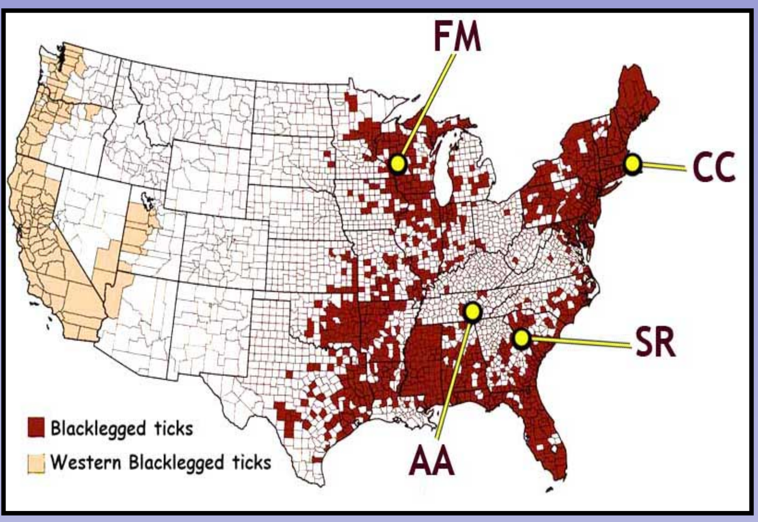
Abstract

Northern blacklegged ticks, *Ixodes scapularis*, the primary vectors of Lyme disease in North America, were sampled at four sites in the eastern and central United States. Tick abundance was strongly related to relative humidity in leaf litter, which was related to forest canopy cover. Also, larval phenology was related to relative humidity in leaf litter. Seasonal declines in nymphal activity, as measured by flag samples, were not clearly related to environmental moisture, but our data suggest a possible role of host finding. Previous reports have disagreed on the effects of environmental factors on tick abundance and Lyme disease risk. These inconsistencies apparently result from the use of broad weather variables that do not capture the complex and subtle relationships among environmental factors and tick population parameters.

Introduction

Investigators have presented conflicting results about the relationships between weather variables and Lyme disease risk. Ginsberg et al. (1998) showed that tick fluctuations were similar at different sites in southern New York and New England, suggesting that factors that operate on a regional scale, like weather, influence tick populations fluctuations. Subak (2002) and McCabe & Bunnell (2004) found relationships between Lyme disease cases and various broad measures of environmental moisture. Alternatively, Ostfeld et al. (2006) found that neither precipitation nor temperature added significantly to regression models that used acorn or rodent densities to predict densities of infected nymphal *Ixodes scapularis*. In this study, we examine the effects of environmental factors, and their interactions, on tick densities and phenologies at several sites in the eastern United States.



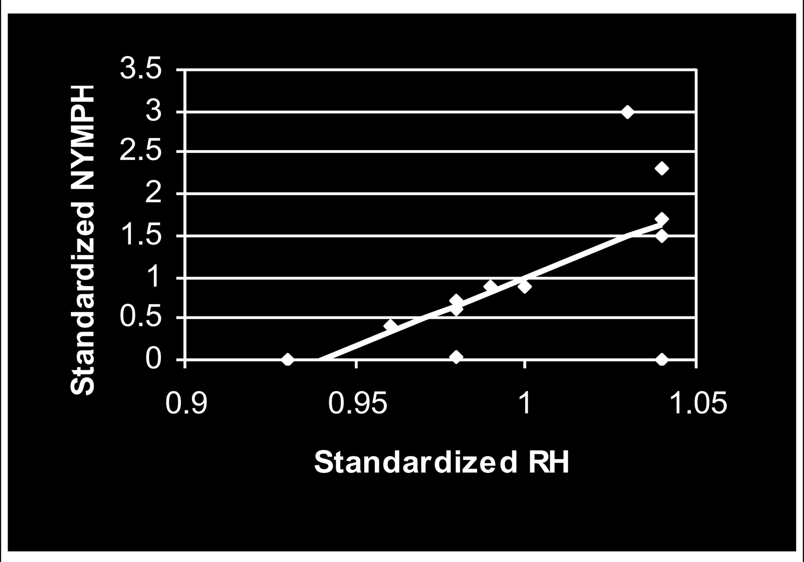
Methods

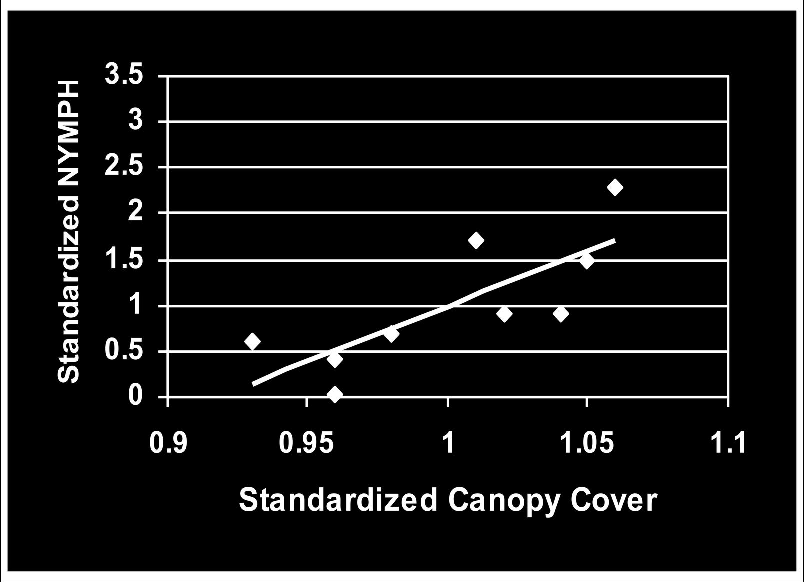
Ticks and environmental data were collected at four sites: Cape Cod, MA (CC), Fort McCoy, WI (FM), Arnold AFB, TN (AA), and Savannah River Site, SC (SR). At each site, three 7x7 sampling arrays with Sherman traps 15m apart were established, each with a HOBO temperature/RH data logger at leaf litter level and another at 0.5m height near the center of the array. Ticks were collected by flagging/dragging (Forty-eight 15m samples with a $1m^2$ flannel flag) and from rodents (from 49 Sherman traps) roughly every other week from May through October. Vegetation data, including tree and shrub density, canopy cover, and ground cover, were collected at each array using standard methods.

Results

To control for differences in overall abundance among sites, tick densities were standardized at each site by dividing tick density at each array by the mean of the three arrays at the site. Environmental variables were standardized in the same way. Statistical comparisons of these standardized scores among sites is somewhat ad-hoc because the scores are not strictly independent. Nevertheless, relative humidity at leaf litter level ($r^2 = 0.817$, $p = 0.001$) and canopy cover ($r^2 = 0.604$, $p = 0.014$) clearly showed strong relationships with tick density.

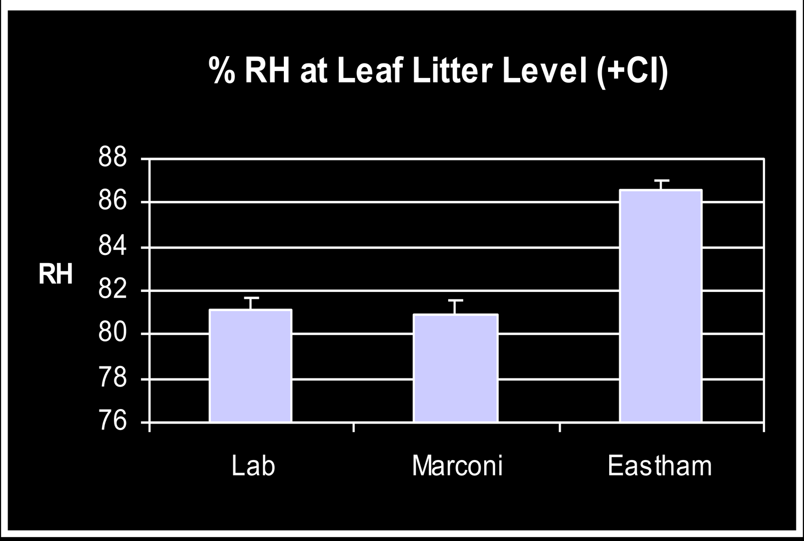
Tick density





Relative humidity was correlated with canopy cover ($p = 0.022$) and when RH was taken into account, canopy cover did not add significantly to the regression model ($p = 0.500$), suggesting that the effect of increased canopy cover on tick density was to increase RH in the leaf litter. The best 2-variable model ($R^2 = 0.907$, $p = 0.001$) included RH in the leaf litter (std coeff = 1.053, $p = 0.0003$) and percent groundcover (std coeff = -0.335, $p = 0.053$), perhaps because excessive groundcover interfered with flagging.

Mean relative humidity in leaf litter at the Lab and Marconi arrays were below the 82% threshold at which tick survival is affected (Rodgers et al. 2007). Mean relative humidity was above this threshold at the Eastham array.

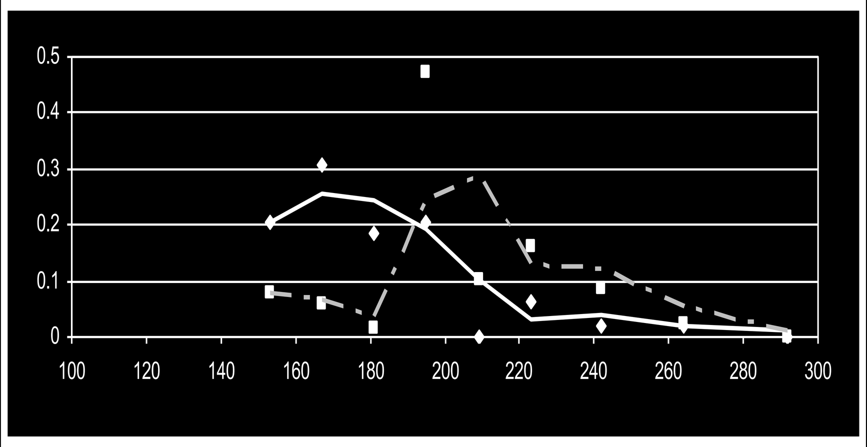


Tick phenology

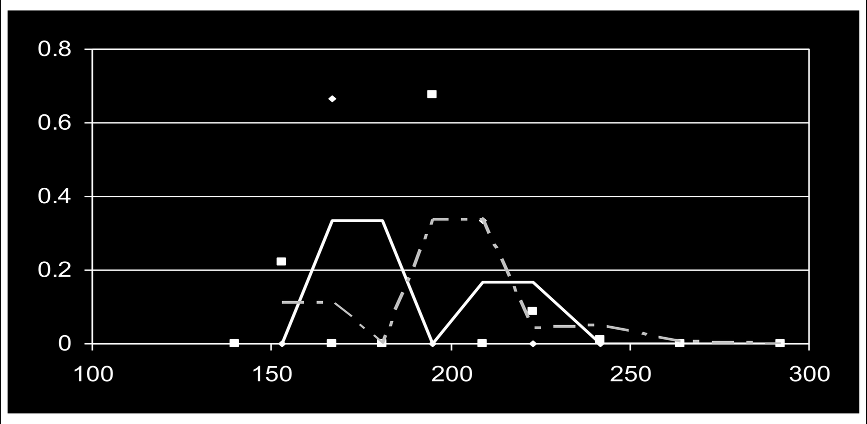
Larval ticks: Larval phenologies (larvae = dashed lines, nymphs = solid lines below) differed substantially among the three arrays at Cape Cod National Seashore($G = 608.58$, $df = 14$, $p < 0.001$). The activity peak was shifted later in the season and the period of activity was longer at the Eastham site. Eastham also had the highest relative humidity at leaf litter level of the three arrays.

Phenologies of *Ixodes scapularis* immatures at Cape Cod sampling arrays - running averages of proportions

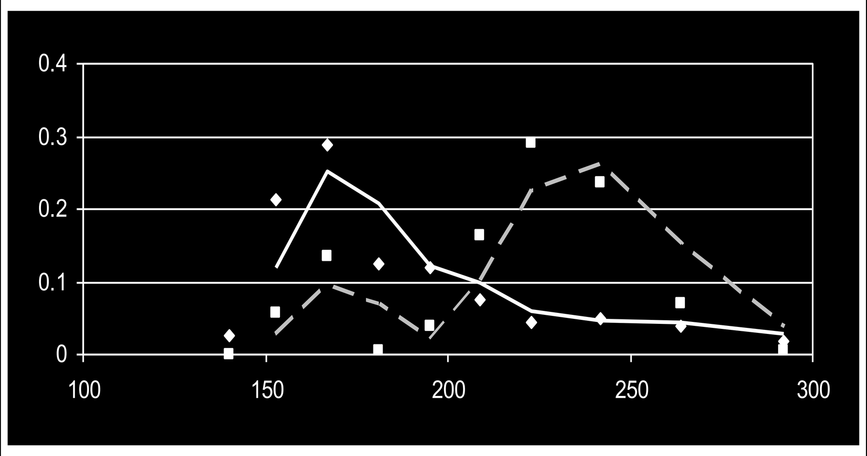
Lab



Marconi



Eastham



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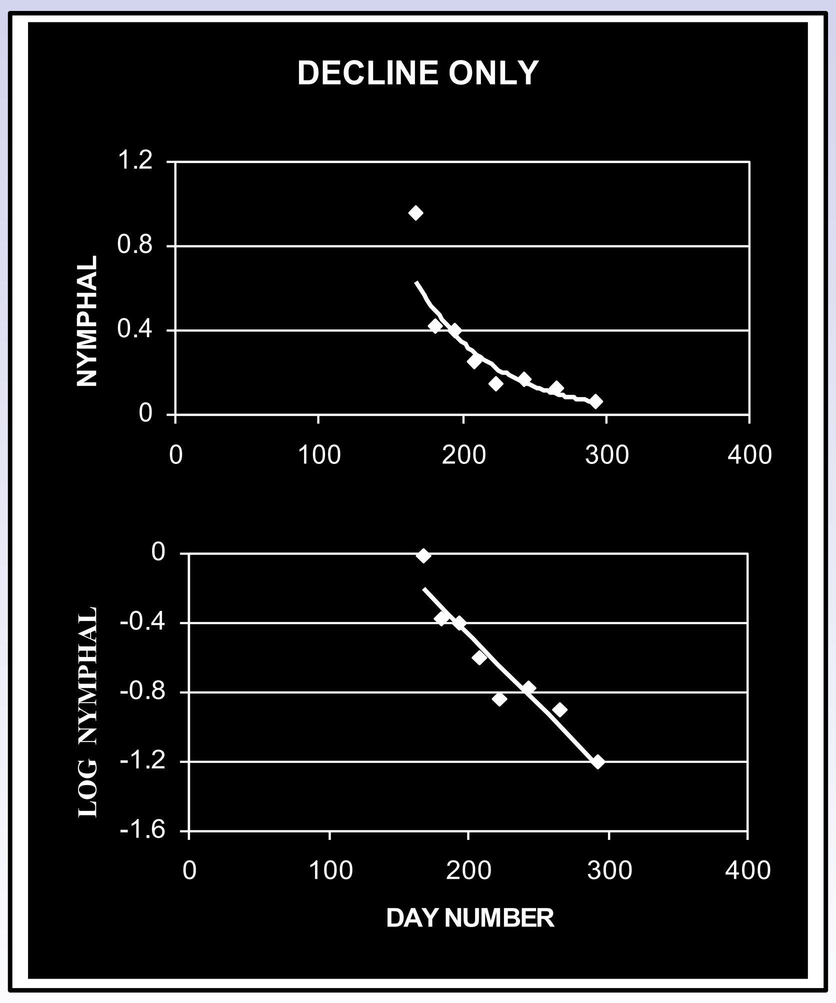
Nymphal ticks: The increase phase of nymphal activity presumably results from factors affecting reactivation of ticks after overwintering (Hancock et al. 2011), but the decline phase results primarily from tick loss due to mortality and host finding. Decline at the Eastham array on Cape Cod was exponential (as reported by Vail & Smith 1997 in New Jersey). The rate of decline can therefore be quantified as the slope of a plot of log density through time.

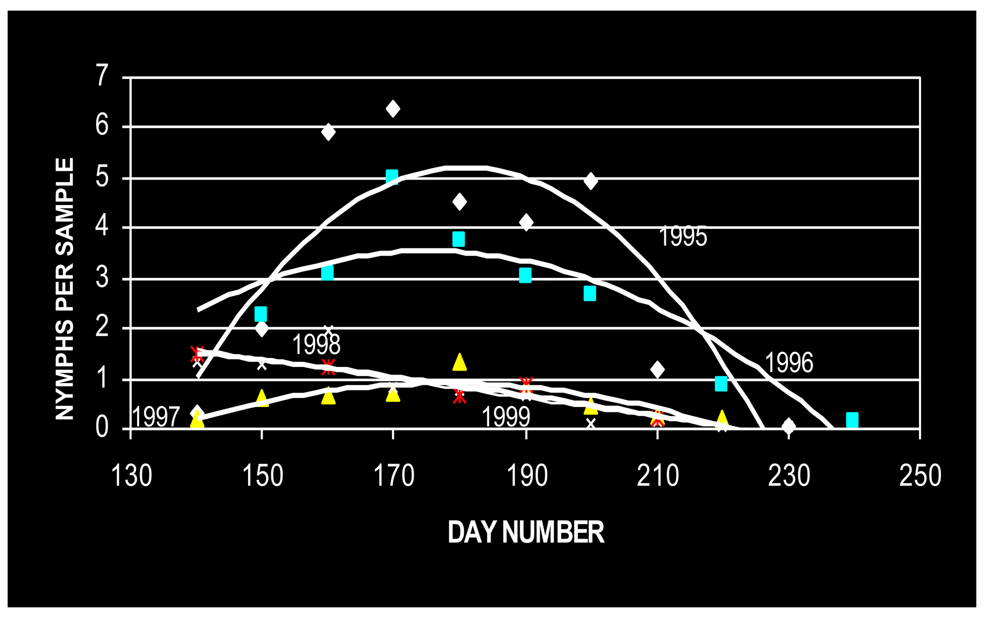


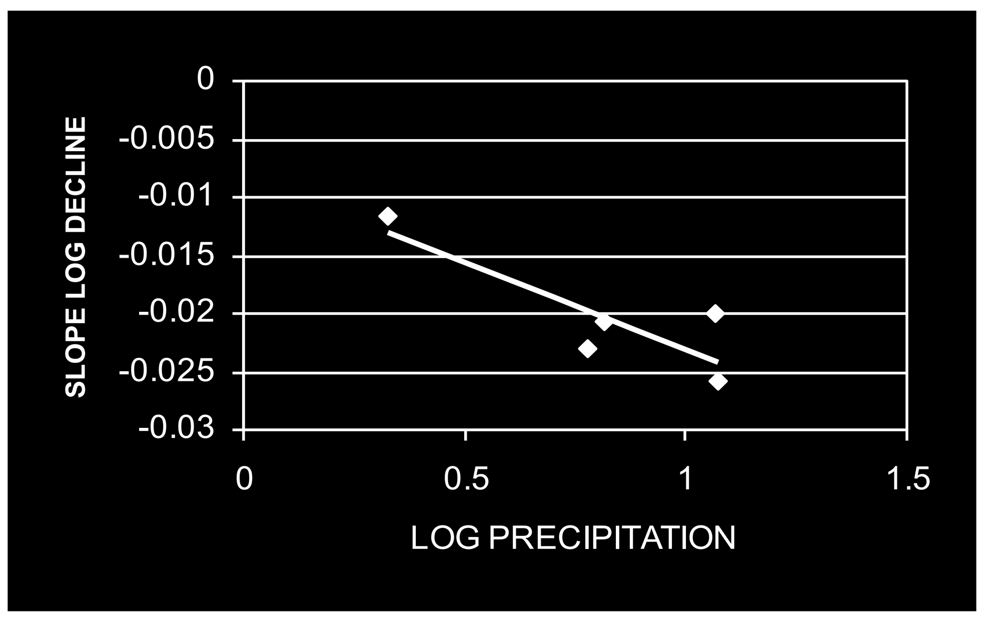
Environmental factors and seasonal decline of nymphs

The standardized slope of log decline was not related to the standardized slope of RH at the leaf litter level at the six Cape Cod and Fort McCoy arrays (p = 0.356). At the Eastham site on Cape Cod, the number of nymphs per sample during the decline phase was related to both tick age (day number, $p = 0.017$) and cumulated hours below 80% RH ($p = 0.011$). However, cumulative hours below 80% RH did not contribute significantly to the regression beyond the effects of tick age. Including host density in the analysis (proportion of traps with mice), the best 2-variable model ($R^2 = 0.853$, $p = 0.008$) included day number ($p = 0.0038$) and mouse abundance ($p = 0.044$), suggesting that host finding was an important contributor to nymphal decline in flagging samples.

Nymphal phenology, Fire Island, NY, 1995-1999

We examined the role of environmental moisture using data collected at the Lighthouse Tract on Fire Island, NY, during the 1990's (Ginsberg et al. 2004). Slope of the log decline of nymphs during the five sample years was not related to precipitation ($p = 0.07$), and the direction of the line suggests a steeper slope when precipitation was greater. As at Cape Cod and Fort McCoy, this suggests that lack of environmental moisture did not contribute strongly to the decline phase of nymphs at this site.





Conclusions

Our results demonstrate clear relationships between environmental factors, including relative humidity at leaf litter level, vegetation, and host abundance, with tick abundance and phenology. However, these relationships are complex and are characterized by interactions among environmental variables. Our results are preliminary, and further replication (by repeated sampling at these four sites, as well as additional sites planned for 2011 and 2012) will be needed to draw reliable conclusions. However, the reason for the conflicting results reported by previous investigators seems clear. Tick abundance and Lyme disease risk cannot be reliably predicted using simple, broad-scale weather variables such as temperature and precipitation from weather stations. These variables are too coarse to capture the complex relationships between tick abundance and environmental factors.

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